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The Biophysical Aspects of the Human Body in Cave Diving

When human beings descend beneath the sea, the pressure around them increases tremendously. To keep the lungs from collapsing, air must be supplied also under high pressure, which exposes the blood in the lungs to extremely high alveolar gas pressures and which is called hyperbarism. Beyond certain limits these high pressures can cause tremendous alterations in the physiology of the body, which explains the necessity for the present discussion *(Burakovsky 1981)*.

We sometimes accompanied cave-divers during their work and have studied their most characteristic and easily determinable biological parameters from a medical point of view *(Vincze-Vincze 1987)*. We have determined the pulse rate, frequency of respiration, blood pressure, body temperature and body weight. We have determined these parameters for each diver before and after submersions, and in this way we have a great number of data at our disposal to evaluate *(Vincze-Vincze 1989)* Data obtained before and after submersion (during the readaptation phase) are presented in figures. The time scale was started immediately after submersion in all cases.

A significant increase in pulse rate can be noticed already in the cave-potion of the way, in comparison to the outside normal value (broken line in *Fig. 1*) and this increase was continued strongly after submersion. As is shown in *Fig.1* the readaptation lasts 20-30 minutes. This kind of growth of the pulse rate draws attention to two important dangers and suggest caution from the medical point of view: those persons, whose usual pulse rate is higher than the average and older ones, whose capacity of adaptation is weaker, are advised not to participate in cave-diving.

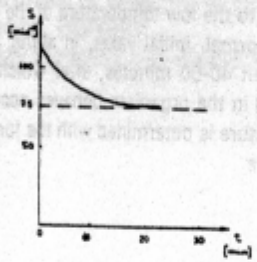

Fig. 1 Variation of the pulse number (S) in the time (t).

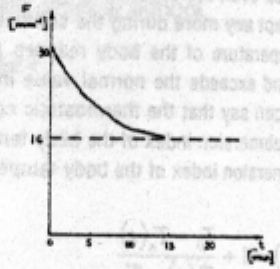

Fig. 2 Variation of the frequency of the respiration (F) in the time (t).

The frequency of respiration generally doesn't show much difference in cave in comparison to the outside normal values, and this can be explained through the fact that cave-divers get used to deep and effective breathing.

After submersion the frequency of respiration suddenly increases in the course of readaptation, but normal values are usually re-established after 15 minutes *(Fig.2)*. It is a well-know fact that cave-divers do regular respiration-training on the surface to continuously regulate the frequency of respiration and to enlarge their vital capacity. From a medical point of view, in case of the slightest pathological symptom in the respiratory tracts the submersion must not be allowed.

Blood-pressure values, in speleological circumstances show a slight - but not significant - decrease in comparison to the normal outside values. As is shown in *Fig.3*, the blood pressure value has a significant increase after submersion, but not in proportion to the pulse or to the frequency of respiration. For the comparison of these physiological parameters we have introduced the indexes of submersion.

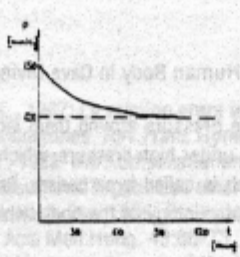

Fig. 3 Variation of the blood pressure (P) in the time (t).

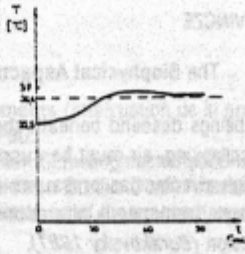

Fig. 4 Variation of the body temperature (T) in the time (t).

These were determined in the following way: we compared the postsubmersion value of the given parameter to its presubmersion value. The consideration of these indexes allows a characterization of the readaptation period which differs for each individual.

In *Fig.4* the variations in body temperature are illustrated in the circumstances given above. The homoiothermic human organism tries to maintain its temperature at a certain constant value, but if the organism remains in a low temperature medium over an extended period of time, the body temperature shows a certain decrease. Taking into account that a speleological field-trip in average lasts more than 12 hours, and sometimes also a few days, and that the temperature of the external environment is about 6-10^{0}C, we have to deal with a decrease of body temperature of about 0.5^{0}C. We checked the body temperature also during submersion. As in the caves the temperature of the water is even lower than that of the air (2-8^{0}C), the body temperature decreases even more, about 1-1.5^{0}C, and this is a very important parameter in cases when the cave-diver cannot adapt any more during the submersion to the low temperature of the water. In the course of readaptation the temperature of the body reaches the normal, initial value, in about 30-40 minutes, then it continues growing and exceeds the normal value in about 40-60 minutes, after which time it returns to the normal level. So we can say that the thermostatic control in the organism behaves according to the oscillator model and that the submersion index of the body temperature is determined with the formula in *Table 1.*

Table 1. Submersion index of the body temperature

$$I_T(t) = 1 + \frac{T_0 - T_a(t)}{T_a(t) - T_c}$$

T_n - normal body temperature (before dive)
T_a - actual body temperature (after dive)
T_c - critical temperature under which physical exercise is impossible. $T_c = 35^0$C

Table 2. Index of readaptation

$$I_{Re}(t) = 0.3*I_S(t) + 0.3*I_F(t) + 0.1*I_P(t) + 0.3*I_T(t)$$

I_{Re} - index of readaptation
I_S - submersion-index of pulse
I_F - submersion-index of respiratoric frequency
I_P - submersion-index of blood pressure
I_T - submersion-index of body temperature
t - time passed since submersion

The body weight also shows a loss after each submersion.
We considered these parameters important, because in this way the average period of readaptation can be determined for each member of the group. For the characterization of the period of readaptation we have introduced the index of readaptation, which can be determined with the help of indexes of submersion see Table 2.
We have determined the constants using our previous physiological and biophysical knowledge. The changing course of the index of readaptation is presented in Fig.5. It is advisable to determine it for each cave-diver individually, because in this way the accidents caused by submersion can be avoided (Miles 1986).

References

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